VIII. *Experiments and Obſervations in Electricity.* By *Mr.* William Henly, *F. R. S.*

P A R T I.

Remarks on the effects of lamp-black and tar, or lamp-black and oil, as protectors of bodies from the ſtroke of lightning; with ſimilar effects produced by experiments in the artificial electricity.

Read, Jan. 16 and 23, 1777.

DR. LEWIS, in his Philoſophical Commerce of Arts, p. 364, mentions a remarkable inſtance of the effect of a coating of lamp-black and tar, in preſerving thoſe parts of the maſt of a ſhip, which were covered with it, from damage by a ſtroke of lightning which ſhivered the other, that is, the uncoated parts of it, in a very extraordinary manner. The account is recited at large in vol. XLVIII. of the Philoſophical Tranſactions. Captain NAIRNE, in his Remarks on the Effects of Lightning, on the maſts of ſeveral veſſels which were ſtruck in the Baſon at Quebec[(a)], mentions, in his letters to ſome friends in London, no leſs than five inſtances, where the lightning paſſing over thoſe parts of the maſts of the ſhips which were covered with lamp-black and tar, or painted with lamp-black and oil, without the leaſt injury, ſhivered the uncoated parts (tearing out ſplinters five or ſix feet in length, and ſix or eight inches deep) in ſuch a manner as to render the maſts entirely uſeleſs. A very curious inſtance of this kind hath lately been communicated to me by a learned and ingenious member of the Royal Society, from whom I received the account which I ſhall here inſert *verbatim*,

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(a) His own ſhip, the *Generous Friends*, was twice preſerved there by his conductor.

"On the firſt of April, 1776, being on board a brig " in the latitude 34° N. our veſſel was ſtruck with light- " ning, which diſabled our fore-maſt. Upon getting the " whole of the top-maſts down upon the deck, I ob- " ſerved the following particulars, with regard to the " courſe and effects of the electrical matter. The light- " ning had firſt ſtruck the pinnacle of the fore-top-gal- " lant-maſt (on which, at that time, there happened to " be no iron ſpindle, as uſual) which it juſt ſplit ſlightly " for about two feet and a half, where it was painted " with lamp-black and oil (I could not, however, aſcer- " tain whether this part of the maſt had been newly " ſplit or not: it might have been firſt occaſioned by " driving in the iron ſpindle, whereon a vane is uſually " placed; for there was a hole where ſuch a ſpindle had

" been fixed) and then the lightning immediately ſhi-
" vered the reſt of that maſt as far as it was greaſed, till
" it met the bottom of that and the top of the top-maſt,
" which had likewiſe been coated over with lamp-black
" and oil, on an old coat of tar. Over theſe it glanced,
" without any perceptible effect, till it reached that part
" of the top-maſt which was alſo greaſed; this part it ſhi-
" vered, ſplitting off large ſplinters which were thrown
" on the deck. The lower part of the fore-maſt being
" tarred, the lightning ſlid over it for about nine
" feet, without the leaſt mark of violence; then darted
" into the fore-maſt, where it was greaſed; rived it ter-
" ribly, tearing off ſplinters as large as a man's arm, and
" four or five feet long, all the way down. It continued
" this courſe till it again met a coat of tar, which was
" laid on the maſt for more than five feet above the
" deck; here its effects on the maſt diſappeared, and its
" courſe ſeemed to be divided different ways by two at-
" tractive bodies of iron; one, in a cleet faſtened to the
" fore-maſt, about ten inches below the top of the laſt
" mentioned coat of tar, by two large ſpike-nails: this
" cleet with the nails was entirely ſtruck off; the light-
" ning then tore the canvas coating round the foot of
" the maſt (about a yard below the cleet) without any
" other hurt to the maſt itſelf; and from thence was
" attracted

" attracted by a large anchor lying in a horizontal poſi-
" tion on the deck, about two feet from the maſt. All this
" part of the electrical matter ſeems to have been then
" diſcharged by the different conductors of the two flukes
" and the main ſhank of the anchor, without any other
" viſible effect than breaking a piece out of a large iron
" pot, ſtanding in an immediate direction to one of the
" flukes, and about ten inches diſtant. The other divi-
" ſion of the electrical matter darted from the maſt to
" the belfry, about fifteen inches diſtant, tore off two
" cleets faſtened to it by large iron nails; then deſcended
" to the large iron hinges which hold the palls or ſtops
" (joined to the belfry-poſts) of the windlaſs, where,
" after tearing off a ſmall nail or two, it totally diſap-
" peared. The belfry which was painted was much
" ſplit, but not broke to pieces. The moſt remarkable
" part of this accident, and for which the whole relation
" is given, is, the effect of the tar and lamp-black and
" oil as repellents of the electrical matter; for in four
" inſtances, 1ſt, at the head of the fore-top-gallant-maſt;
" 2dly, at the bottom of that and head of the top-maſt;
" 3dly, at the bottom of the top-maſt and head of the
" fore-maſt; and 4thly, at the bottom of the fore-maſt;
" the lightning had glanced over all thoſe parts without
" doing the leaſt damage, and had regularly darted into,

“ and ſhivered all the intermediate parts of thoſe maſts, “ where they were covered with greaſe. This appears “ ſo extraordinary to me, that I thought proper to take a “ note of it upon the ſpot, in order to occaſion the making “ of ſome philoſophical inquiries and experiments on “ the ſubject by thoſe more capable of accounting for it “ than myſelf: and for that reaſon the above relation “ may be depended on as juſt and true, after a repeated “ and critical examination of the ſeveral parts of the “ maſts which I have deſcribed. W. D.”

In conſequence of this relation, and the hint which concludes it, I have been induced to make the following experiments. 1ſt, A glaſs tube, eight inches long, with a bore or cavity of about a quarter of an inch diameter, being filled pretty cloſely with lamp-black, and each end ſtopped with a bullet, the ſtem of which juſt entered, and was cemented in the cavity of the tube, conducted the charge of a jar containing three ſquare feet of coated ſurface inſtantaneouſly, but with ſcarce any exploſion. 2dly, Such a tube being filled with a mixture of lamp-black and oil (as uſed by the painters) entirely failed to conduct the ſhock. 3dly, The outer ſurface of ſuch a tube being painted with lamp-black and oil, and excited with dry warm flannel, acted (the tube being alſo dry and warm) as a very ſtrong negative electric. 4thly, A piece of poliſhed plate glaſs being introduced into the circuit, the ends of the wires which compoſed the circuit were laid at about an inch and an half from each other upon the ſurface of the glaſs, when the jar above-mentioned being diſcharged, the poliſh of the glaſs was always torn off in an irregular and deep line, extending from one wire to the other; but if a piece of glaſs painted with lamp-black and oil were thus introduced into the circuit, and the diſcharge made as before, not the ſmalleſt trace of the electricity could ever be perceived on its ſurface. 5thly, If inſtead of the glaſs, a ſlip of writing-paper was introduced into the circuit, it was torn in pieces by the exploſion, much of it flying about the room in the form of fine flue or down. 6thly, A ſlip of the ſame paper, painted with lamp-black and oil, received not the leaſt injury, nor ſhewed the ſmalleſt trace of the electricity upon its ſurface; but the common oiled paper, without lamp-black, was torn conſiderably, though not ſo much as the paper unoiled[(b)]. When the charge of the jar above-mentioned is made to paſs between the ſurface

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(*b*) Mr. CAVALLO, who hath ſince repeated theſe experiments, finds, that if the paper be very thinly painted with the lamp-black and oil, it will be torn by the exploſion; but having tried a piece of the ſame that I had uſed in my experiments, he was not able to make the leaſt impreſſion on it. Lamp-black and tar therefore, on account of the greater tenacity of the latter, and its being equally a non-conductor, ſeems to be the moſt proper for the purpoſe.

of thick plate glaſs, and that of a cylinder of ivory three-quarters of an inch diameter, preſſed by a weight of about ſix or eight ounces Troy; the glaſs is always ſhivered into very ſmall fragments, and part of it is ſometimes reduced to an impalpable powder. But 7thly, If the plate of glaſs be covered with a ſlip of writing-paper, painted with lamp-black and oil, or with a ſlip of oiled ſilk (ſuch as is frequently uſed for garments) the charge paſſes over theſe ſubſtances without leaving the ſmalleſt trace on either of them, though the glaſs under them be broken by the blow of the exploſion.

From theſe experiments, and the obſervations above recited, I think the following corollaries may be deduced. 1ſt, That a charge of electricity, or a ſtroke of lightning, which is the ſame thing, paſſes, in many caſes, upon the ſurface of bodies, in a much larger proportion than through the interior ſubſtance of them, as appears by the maſts of ſhips, coated with lamp-black, &c.(c), and by the experiment above recited, with the cylinder of ivory and the glaſs &c.; for in this experiment, the charge being reſiſted by the ivory (which however is ſometimes ſplit by the exploſion) forces a paſſage between that and the glaſs, and being there confined by heavy weights, exerts its expanſive power in ſuch manner as to reduce to the ſmalleſt fragments the plate of glaſs then expoſed to its violent operation. 2dly, This violent effort of the electricity produces not the leaſt effect upon the ſurface of the ſlip of paper painted with lamp-black and oil, or upon a ſlip of oiled ſilk, placed in the ſame ſituation. 3dly, May not therefore a coating of lamp-black and tar, or lamp-black and oil, be in ſome caſes uſefully applied on ſlight buildings of wood, &c. to preſerve them from damage by lightning, as well as to prevent thoſe large cracks and rents (the uſual effect of the heat of the ſun) from being made in them? 4thly, As the effect of the lightning on the maſts of ſhips has been in ſo many inſtances prevented by a coating of lamp-black and tar, or lamp-black and oil, it ſeems probable, that a ſafe and fixed conductor might be applied to them in a very cheap and convenient manner, as follows; *viz.* let all thoſe parts of the maſt which are uſually greaſed, be provided with plates of metal three inches broad, which plates might extend a few inches upon the other parts of the maſt which are coated with lamp-black and tar, or lamp-black and oil; and thus by the conductor of metal, and the protector of lamp-black and tar, placed alternately and extending the whole length of the maſt, it would probably be preſerved from damage by lightning. A metallic communication might be made from the maſt to the water in the manner I have before mentioned, in Phil. Tranſ. vol. LXIV. p. 412. This method of making conductors to ſhips, from its ſimplicity and practicability, I had ſome thoughts of recommending to my acquaintance in the marine department; but there is one objection to it, which I think a very material one, and ſhall therefore ſtate it in its full force: it is this; the lamp-black and tar, or lamp-black and oil, though they protect, by their property of repelling the electric matter, thoſe parts of the maſt which are coated with them, yet being perfect non-conductors, thoſe things or perſons which might happen to ſtand in their vicinity (as in the tops, &c.) would be in danger of a ſevere ſtroke, perhaps deſtruction, by the lightning. How far the other oil colours, *viz.* thoſe prepared from minerals and metals, may anſwer theſe purpoſes, may perhaps deſerve enquiry, and the more ſo, as the experiments are not difficult to make. The belfry-poſts painted with white lead, mentioned in the letter above recited, were much ſhivered. 5thly, As oiled ſilk ſeems to be ſo good a ſecurity againſt the effects of a charge of electricity, may not garments, *viz.* cloaks and hats, covered with that ſubſtance, contribute in ſome meaſure to protect the wearers (if overtaken by a ſtorm) from a ſtroke of lightning? particularly, if the precautions be properly attended to, which I have before recommended from Dr. WINTHROP, in Phil. Tranſ. vol. LXIV. p. 151.

(c) See a curious inſtance of this kind in M. ADANSON's Voyage to Senegal, p. 239.

PART II.

On the electricity of chocolate: and the reſtoration of that property to it, when loſt, by melting it together with a ſmall quantity of olive-oil.

HAVING been informed by my ingenious friend Mr. GEORGE ADAMS, philoſophical inſtrument-maker to his majeſty, that Mr. SANDERS, an eminent manufacturer of chocolate, had frequently obſerved a very vivid light flaſhing upon its ſurface, when cooling in the tin pans in which it is received from the mill; particularly in clear, froſty evenings, when it would alſo ſtrongly attract light ſubſtances, ſuch as ſmall particles of duſt, bits of paper, ſtraw, thread, &c.(d); I was very deſirous to aſcertain, if I could, the cauſe of theſe phenomena. For this purpoſe I waited on Mr. SANDERS, in company with Mr. ADAMS, and made the following experiments. 1ſt, A large cake of chocolate being turned out of the tin pan, in which it had been ſet to cool; I preſented towards it Mr. CANTON's electrometer, and obſerved that, at ſix inches diſtance, the balls began to diverge; and when they came within two inches of the chocolate (being ſuſpended over it) their divergence was full an inch and an half, and upon examining their electricity, I found the chocolate to be in a *plus* or poſitive ſtate. 2dly, Having ſeparated another large cake from the pan, I touched it repeatedly with the knob of a ſmall phial, properly prepared for the Leyden experiment; then bringing that knob gently toward one of my knuckles, I ſaw a ſpark between them, and had a ſmall ſenſation in my knuckle. 3dly, Having ſeparated another cake of chocolate from the tin pan which contained it, I touched the cake repeatedly with the braſs ball on the neck of my Leyden *vacuum*, or analyſis of the Leyden bottle(e), and inſtantly perceived a moſt beautiful and large pencil of rays darting from the wire, and ſpreading themſelves through the bulb towards the coated part of the bottle. 4thly, Changing the poſition of the bottle, I preſented the coated bulb towards the chocolate, and then perceived (as I expected) a ſmall luminous ſpark upon the point of the wire in the neck of the bottle; completely proving the electrical quality of the chocolate, and aſcertaining its direction in the experiments.

(d) The wax-chandlers alſo, in forming their ſticks, &c. of wax, are frequently ſpectators of theſe effects of electric attraction.

(e) Deſcribed in Phil. Tranſ. vol. LXIV. p. 400.

Before I had an opportunity of making this complete inveſtigation, I had ſeparated a piece of chocolate from the tin pan in which it had been cooled, and accidentally left, for ſome months, under an open counter in a ſhop, expoſed to duſt, damp air &c.; notwithſtanding which, on its ſeparation from the pan, it attracted a thread of trial at a quarter of an inch diſtance. I then took a quarter of a pound of chocolate, and having melted it in an iron ladle, poured it into a tin pan, and the next day (it being perfectly cooled) ſeparated it from the pan, and found it ſtrongly electrified *plus*; but as the electricity was ſoon loſt by handling (owing, I ſuppoſe, to the large quantity of conducting matter contained in it) I melted it again, but produced no electricity; which I imputed to the chocolate having become very dry and powdery. I therefore melted it a third time, adding a little oil of turpentine; but this trial alſo (perhaps from the evaporation of the ſpirit) failed. I then melted it the fourth time, and added a ſmall quantity of olive-oil, ſufficient as I imagined to reduce it again to its original conſiſtence, and having cooled it in the tin pan as before, I found on removing it, that its electricity was completely reſtored. The large proportion of phlogiſton in oil is well known; and as the addition of oil to the chocolate completely reſtored its electricity when loſt, is not this an indication of a great affinity at leaſt between phlogiſton and the electric fluid, if indeed they be not the ſame thing[(f)]? Further, as electricity is produced in the chocolate by heat and friction, and manifeſted by its uſual phenomena in the cooling of that ſubſtance, *query*, may not electricity be produced from the other oily nuts, kernels, or ſeeds (particularly thoſe of the torrid zone) treated in the ſame manner?

However, as the electric matter is reſident in, and may be diſengaged from, all the ſubſtances we are acquainted with; as the air is at all times replete with it; as its operation is ſo ſecret, ſo rapid, and at times ſo tremendous; as it is ſo eaſily excited or put in action by friction, by heating and cooling, and perhaps by means we are totally unacquainted with; I think we may ſafely conclude, that electricity, as it is one of the moſt powerful, is alſo one of the moſt important, agents in nature. Many uſeful diſcoveries have been made reſpecting the action, influence, and effects of this ſubtile fluid; but certainly much remains to be done, and the field for future labourers ſeems daily to enlarge. Indeed, notwithſtanding the number of diſcoveries in electricity this age may juſtly boaſt of, I cannot but be of opinion (which I men-

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(f) A thick ſcum from the ſurface of ſome linſee-doil expoſed to the air, and thoroughly dried, became a very ſtrong negative electric.

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tion as an incitement to the ſtudy) that, compared with the facts ſtill undiſcovered in that branch of philoſophy, they bear but a very ſmall proportion.

PART III.

Obſervations on ſome new and ſingular phenomena in excited and charged glaſs; with experiments made in conſequence of theſe phenomena, further illuſtrating the Franklinian theory of the Leyden bottle; and a deſcription of the apparatus conſtructed for that purpoſe by Mr. HENLY.

HAVING carefully repeated the experiments with the two coated plates of looking-glaſs, mentioned in my paper on Mr. VOLTA's machine, and finding with Mr. LANE, that they exactly agreed with the account given by Mr. SYMMER and Mr. EELES, I was deſirous to be ſatisfied whether glaſſes of a different thickneſs would be differently affected in the experiment. For this purpoſe I tried two large ſquares of crown or window-glaſs, and found them to charge and diſcharge exactly as the looking-glaſs plates had done; but on trying the experiment with two plates of Nuremburg glaſs, commonly called Dutch plates, I was not a little ſurpriſed to find that each of the plates, when ſeparated after charging, had a poſitive and a negative ſurface; and that having replaced them, and made the diſcharge as in the Leyden experiment, the electricity of all the ſurfaces was changed, though it appeared to be very ſtrong, and continued to give repeated flaſhes of light, when the plates were alternately cloſed, touched, and ſeparated, as the looking-glaſs plates above mentioned. If a clean dry uncoated plate of looking-glaſs was placed between the coated plates, either of looking-glaſs or crown-glaſs, before they were charged; that uncoated plate was always found, upon ſeparating them after charging, to be electrified negatively on both its ſurfaces; but if it was put between the Dutch plates, it acquired, like them, a poſitive and a negative electricity. As this phenomenon was not ſatiſfactorily accounted for, it occaſioned much converſation with reſpect to Dr. FRANKLIN's theory of the Leyden bottle, which I had myſelf (as I imagined) ſatisfactorily explained and even demonſtrated. I was, however, ſoon convinced, that that theory is not ſo generally received as I imagined; for I met with a number of gentlemen who not only doubted, but ſeemed abſolutely to deny it. This induced me to make ſome further experiments, in order (if I could) more fully to illuſtrate that theory, and to put the matter out of doubt. For this purpoſe a pretty large jar was coated and furniſhed as in fig. I. A is the jar; BB the tin-foil coating; C a tinſtand which ſupports the jar; D a ſocket of metal which ſupports a rod of glaſs E; F a curved wire or plate of metal with points, not very ſharp; this wire or plate of metal is faſtened to the end of a braſs rod G, which rod is moveable at pleaſure in a ſpring tube H, that tube being fixed by a ſocket upon the top of the glaſs rod E. The charging wire of the jar communicates with both parts of the inſide coating of the jar by horizontal wires (the ends of which are bent a little downwards) fixed at right angles to each other, in order to prevent ſhaking and ratling.

THE USE OF THE DOUBLE COATED JAR.

According to Dr. FRANKLIN's theory, the ſame quantity of the electric matter which is thrown upon one of the ſurfaces of glaſs in the operation of charging it, is at the ſame time repelled or driven out from the other ſurface, and thus one of the ſurfaces becomes charged *plus*, the other *minus*; and that this is really the caſe is, I think, ſatisfactorily proved by this contrivance. For example, place the jar as uſual, with the knob in contact with the prime conductor; then work the machine, and the apparatus being perfectly dry and in good order, a ſmall luminous ſpark will appear upon the upper point of the wire F (a plain indication that the point is then receiving electricity from the upper ring of coating on the outſide of the jar) and a fine ſtream or pencil of rays will at the ſame time fly off, beautifully diverging from the lower point of the wire F upon the bottom ring of coating on the jar. When theſe appearances ceaſe, which they will as ſoon as the jar becomes charged, let a pointed wire be preſented towards the prime conductor; this will ſoon diſcharge the jar ſilently, during which the lower point of the wire F will be illumined with the ſmall ſpark, while the upper point of the wire will throw off a fine pencil of rays, diverging towards the upper ring of coating, to which it ſtands contiguous, as upon Dr. FRANKLIN's hypotheſis it ought to do. A wire of the ſame form as that marked F may be inſerted on a ſmall electric ſtand, fitted by a proper baſe to the bottom of the jar on the inſide; this will ſhew the appearances when the jar is charged negatively.

The ſame experiment may be very conveniently made with a large pane of crown glaſs(g), coated in two places at a proper diſtance from each other (fig. 2.) leaving a ſufficient quantity of glaſs uncovered quite round the two coatings. This coated plate of glaſs ſhould be fixed in a frame, and mounted upon a proper electric ſtand. Another ſtand of glaſs or ſealing wax ſhould be provided, to ſupport a wire or piece of metal placed horizontally, and curved ſo as to bring the ends of it, which ſhould have blunt points, within half an inch diſtance of the two tin-foil coatings on one of the ſurfaces of the glaſs. On the oppoſite ſide of the glaſs, two wires, bluntly pointed, are alſo to be employed; one of theſe is to communicate with the prime conductor, and to throw off the electricity from thence upon one of the coatings of tin-foil placed contiguous to it; the other wire is to communicate with the earth, ſtanding in a perpendicular direction, with the point bent towards and reaching within half an inch of the other coating of tin-foil (on the ſame ſurface of the glaſs) to receive the electricity thrown off by that coating, while the oppoſite ſide is charging.

(g) Mine is eighteen inches by fourteen inches.

EXPERIMENT.

The apparatus being perfectly dry (the uncoated part of the glaſs and the frame, &c. ſhould be varniſhed), clean, and in good order; the plate of glaſs ſhould be ſo fixed, that each of the four coatings of tin-foil may come within half an inch of the point of the wire oppoſed to it. The apparatus being thus placed, if a powerful machine be worked in a dark room, the electricity will be ſeen to iſſue from the point of the wire in contact with the prime conductor upon one of the tin-foil coatings A (fig. 3.) charging it poſitively. The coating B (fig. 3.) on the other ſide of the glaſs throwing off, at the ſame time, an equal quantity of the electric matter, (viſible in the form of a ſmall luminous ſpark upon the point of the inſulated wire F) is thus left in a negative ſtate. The electricity paſſing along the inſulated wire, flies off from the other point of it in a pencil of rays, diverging upon the tin-foil coating C (fig. 2.) on the ſame ſide of the glaſs, charging it poſitively; while the oppoſite coating D (fig. 3.) throws off its electricity, which is received in a ſmall ſpark upon the point of the wire (G) oppoſed to it, and communicating with the earth. Thus, by the ſame operation of the cylinder, may a poſitive and a negative charge of electricity be obtained at the ſame time upon each ſurface of the glaſs; and by applying two curved diſcharging rods (which ſhould have glaſs handles) at the ſame inſtant, ſo as to come nearly into contact with the coatings upon each ſurface of the glaſs, the whole will be diſcharged together; or if a pointed wire be preſented near to the prime conductor, they will all be diſcharged ſilently, and then the appearances on the points of the wires will all be reverſed; that which was a bruſh or pencil of rays being now a ſmall luminous ſpark, and that which was a luminous ſpark being a bruſh or pencil of rays. If the machine be very powerful, the rubber may be inſulated, and a blunt pointed wire, communicating with the earth, may be placed within half an inch of it; this wire, while the plates are charging, will throw off a beautiful pencil of rays diverging upon the rubber, and thus compleatly exhibit the progreſs of the electricity through all the apparatus, from its exit out of the earth to its entrance into the earth again: and its return may be manifeſted by reverſing all the appearances upon the points of the wires, in the operation of diſcharging the glaſs ſilently by a pointed wire preſented toward the prime conductor, as above directed. Another very ſatisfactory method of demonſtrating the truth of Dr. FRANKLIN's hypotheſis is as follows. I take a bottle, containing about one hundred ſquare inches of coated ſurface, properly prepared for the Leyden experiment, and holding it by the wire, I ſet the coating upon the prime conductor, and charge it negatively (fig. 6.); when charged (if not too dry) the upper edge of the coating will throw off one or more pencils or bruſhes of light into the air, which viſibly incline towards the charging wire of the bottle, and ſometimes actually reach it. If I hold the bottle by the coating, and preſent the knob to the prime conductor, charging it poſitively (the bottle being in a proper ſtate) a ſmall ſpark of light firſt appears upon the edge of the cork in the neck of the bottle, through which the wire paſſes; after a few turns of the globe, this ſpark becomes a fine bruſh, darting out from the cork, and gradually lengthening, till it forms a beautiful arch, the end of it regularly extending downward, till it reaches the edge of the coating and reſts upon it (ſee fig. 5.). I remember, when I firſt ſhewed theſe experiments to my ſincerely reſpected and worthy friend the late ingenious Mr. FERGUSON, F. R. S. he expreſſed great ſatisfaction; and aſſured me, that he thought them ſome of the moſt convincing he had ever ſeen exhibited for the purpoſe. If the bottle be dry, it will, in both caſes, be diſcharged ſpontaneouſly; but if the uncoated part of the glaſs be then breathed upon, the appearances may be produced at pleaſure. I have lately prepared another bottle for this purpoſe, the inſide of which is coated in the uſual manner; but the outſide is covered with ſquare pieces of tin-foil about a quarter of an inch broad, and about three-ſixteenths of an inch diſtant from each other; the bottom is compleatly covered with the coating (fig. 4.). If in charging this bottle, the electricity paſſed abſolutely through the glaſs, it would find a ready conveyance by the coated bottom into the table (and then indeed it could never be charged at all); but the truth is, that this bottle does not become charged till ſtrong flaſhes of electricity have paſſed, diverging in different directions quite round it. If it be diſcharged by bringing a pointed wire near the wire, or the prime conductor, with which it is in contact, the noiſe it occaſions much reſembles the report of a fired cracker; and the uncoated glaſs between the ſpots of tin-foil is very brilliantly illuminated. If the bottle diſcharges itſelf ſpontaneouſly, or be diſcharged ſuddenly, by making a regular communication by the rod between the two ſurfaces of the glaſs, the whole outſide ſurface ſeems to be illuminated. To produce theſe appearances the glaſs muſt be thoroughly dry.

EXPERIMENT.

A ſmooth piece of mahogany, two inches ſquare and five inches long, was hollowed into an elliptic groove, about three-quarters of an inch deep, and painted with lamp-black and oil. Into this groove two wires, terminated by braſs balls each three-quarters of an inch in diameter, were introduced; the braſs balls being placed about one inch and an half from each other: between the braſs balls, at an equal diſtance from each, was placed a ball of the pith of elder, half an inch in diameter, nicely turned in a lathe. The apparatus being thus adjuſted, and the circuit compleated by a ſhort chain, a bottle, containing forty ſquare inches of coated ſurface, was many times diſcharged through it; and whether the bottle was charged poſitively or negatively, the pith-ball conſtantly moved in the direction of the fluid, according to Dr. FRANKLIN's hypotheſis. This is a delicate experiment; but, as I have perfectly ſucceeded in it, I thought it proper to give this ſhort account of it. Perhaps if the pith-ball were ſuſpended by a ſilk ſtring, it might anſwer the purpoſe as well; but this I have not tried.

EXPERIMENT.

In melting ſmall wires ſome inches in length, I have often obſerved the wire to become red-hot, firſt at that end in contact with the diſcharging rod, and the redneſs has proceeded gradually and regularly towards the coating of the jars or battery; plainly and fully demonſtrating the direction of the electric matter in the diſcharge of the jars or battery, which, for this experiment, were always charged poſitively. This phenomenon hath alſo been obſerved by Mr. BELL, and many times by Mr. NAIRNE.

EXPERIMENT.

Before I quit the ſubject of the Leyden bottle, I ſhall mention one experiment more which I have lately made, and which gives a full and compleat anſwer to a paragraph in Dr. PRIESTLEY's Hiſtory of Electricity, 2d edit. p. 465. l. 21. It is this: I procured ſome phials coated with ſilver, by burning it into the very ſubſtance of the glaſs, in ſuch a manner that nothing can remove it without injuring the glaſs together with the metal. Glaſs thus coated and burniſhed has certainly a moſt elegant appearance, has no inequalities or points upon its ſurface, and charges as high and as readily as when it is coated with tin-foil; ſuch glaſſes will diſcharge ſpontaneouſly, and one of them, which was very thin, was burſt by the exploſion; an accident which, by this double annealing, I was in hopes to have prevented, but was ſorry to find myſelf diſappointed.

OBSERVATIONS ON EXCITED GLASS.

In my remarks on Mr. VOLTA's curious little machine lately preſented to the Royal Society, I have obſerved that the electric matter, being once thoroughly excited and put in action, is not ſo ſoon as might be expected reduced again to a quieſcent ſtate, eſpecially in bodies ſo peculiarly adapted to affect each other as theſe appear to be. As a proof, I introduced the experiments with the looking-glaſs, crown-glaſs, and Dutch plates. I alſo mentioned Dr. PRIESTLEY's obſervations on the *reſiduum* of his battery; and in a note to that paper, I added an experiment made by my friend the rev. Mr. HEMMING, F. R. S. who ſhewed me a ſmall bottle, which then attracted a thread of trial, though it had ſtood in a cupboard in his ſtudy ſeventy days from the time he charged it. I alſo mentioned a ſingular effect of his cylinder, which will ſeparate the balls of Mr. CANTON's electrometer, at twelve or fourteen inches diſtance, ſometimes a fortnight after uſing, though the air of the room may have been many times changed, and a variety of methods uſed to deſtroy that power in the interval. As the detail is curious, I ſhall here inſert one ſet of experiments, as I find them regiſtered in a journal, which Mr. HEMMING took the trouble to make for my ſatisfaction. On May 13 1776, the cylinder was uſed, and when placed in the cupboard at 10 o'clock A. M. it ſeparated the balls at ſeven inches diſtance. The power was then entirely deſtroyed by breathing on it, and the electricity marked o. From that time the journal proceeds as follows:

Day.	Hour.	Diſtance at which the balls diverge.
May 13	11 A. M.	7 inches.
14	8 A. M.	13
Breathed on it once,		9
Ditto four times,		8
Door open till	9½ A. M.	5
14	3 P. M.	7
	7 P. M.	6
	10 P. M.	6½

Day.	Hour.	Diſtance at which the balls diverge.
Breathed on it twice,		0 inches
May 14	10½ P. M.	6
15	8 P. M.	13 wind N.
Door open ten minutes,		8
	9 P. M.	13
	10 P. M.	8
The power deſtroyed by flame,		0
16	7 A. M.	14½ wind N.
18	8 P. M.	17 wind N.
	11 P. M.	7½
Deſtroyed by flame,		0
20 A fire in the room the whole day.		
	4 P. M.	2
	8 P. M.	1
	10 P. M.	3
21	7 A. M.	9
	9 P. M.	9
Deſtroyed by flame quite round		0
22	7 A. M.	8½
	10 A. M.	11½ wind N.
Applied flame quite round the cylinder,		0
	1 P. M.	12½

May

Day.	Hour.	Diſtance at which the balls diverge.
May 22	4 P. M.	12½ inches.
	8 P. M. {flame quite round.}	0
	10½ P. M.	2

23d, Mr. HEMMING ſhewed me the experiment, when I ſaw the balls ſeparate at twelve inches diſtance from the cylinder. The cauſe of theſe phenomena is, no doubt, the excited electricity lodged in the pores of the glaſs acting upon the vapour in the air of the room, and producing a greater or leſs effect, as circumſtances may contribute to increaſe or diminiſh its operation. The cylinder was now uſed again, which cloſed this ſet of obſervations. Mr. HEMMING has added a meteorological journal for the time; but the particulars of this I did not think it neceſſary to introduce in the above extract.

A SECOND SET OF OBSERVATIONS.

Feb. 3, 1777, the cylinder was excited, and from the 5th to the 14th no fire had been made in the ſtudy.

Day.	Hour.	Diſtance at which the balls diverge.
14(b)	3 P. M.	7 inches.
	10 P. M.	0
15	9 A. M.	11

(b) This was the firſt time, ſince Auguſt or September, that I had obſerved my cylinder to retain its attractive power longer than twelve hours after being excited, though it was conſtantly kept in the ſame place, and, as well as I can obſerve, under the very ſame circumſtances.

Day.	Hour.	Diſtance at which the balls diverge.
Feb. 15	4 P. M.	8 inches.
	9 P. M.	0
	10 P. M.	0
A large fire in the ſtudy the whole day.		
16	9 A. M.	9
	12	9
	8 P. M.	0
	10 P. M.	0
17	9 A. M.	3
	6 P. M.	2
	11 P. M.	0
18	8½ A. M.	2
Abſent till 22d,	3 P. M.	8
	6 P. M.	2
	7 P. M.	0
	11 P. M.	0
23	8 A. M.	7
	2 P. M.	2
	5 P. M.	0
	9 P. M.	0
	11 P. M.	0
24	9 A. M.	0
	12	0
	3 P. M.	0

Day.	Hour.	Diſtance at which the balls diverge.
Feb. 25	9 A. M.	2 inches.
Abſent till 28th,	3 P. M.	2
	9 P. M.	0
Mar. 1	9 A. M.	0
The fire in the ſtudy put out at noon.		
	10 P. M.	0
2	9 A. M.	0
	1 P. M.	0
Abſent till 8th,	3 P. M.	9½
	6 P. M.	4
	8 9 10 P. M.	0
9	8 A. M.	9
	7 8 10 P. M.	0
10	8 A. M.	8

The cylinder was now excited again, which cloſed this ſet of obſervations. Theſe changes in the electricity ſeem very extraordinary, and I think them not eaſily to be accounted for, as they happened in ſtates of the weather which were totally different. I regret, however, that an accurate and ſenſible hygrometer was not obſerved the whole time; and for ſuch a purpoſe I ſhould recommend Mr. COVENTRY'S, made with a number of circular pieces of iſſue-paper, amounting to a certain weight, thoroughly heated and ſtrung on a thread, kept ſeparate from each other by a ſmall glaſs bead, and ſuſpended on one of the ends of a lever, nicely poized, and turning freely on its axis; the other end ſerving as an index to a graduated ſcale, on which it ſhews the weight of the moiſture imbibed at any time by the papers. This hygrometer, from its extreme ſenſibility, I ſhould chooſe, I ſay, to recommend for this purpoſe, in preference to any other that I have ever ſeen.

HAVING lately had occaſion to ſhew the experiments with the coated Dutch plates to an excellent electrician (Mr. CAVALLO) and having charged them as high as I could, and ſeparated them I think rather more expeditiouſly than uſual, I was aſtoniſhed to find, that the very ſame plates I have ſo often mentioned were now charged, the one poſitively, the other negatively, on both ſurfaces. I then laid them together, and having made the diſcharge as uſual, I ſeparated them, and found one of the plates negative on both ſides, and the other plate poſitive on one ſurface, and negative on the other. Here was a new cauſe of admiration, and I was utterly at a loſs to account for it, as the plates had in every inſtance before

fore uniformly acted as repreſented in my paper. At length I recollected, that this experiment had been made rather more expeditiouſly than uſual: I therefore repeated it, and having allowed ſomewhat more time between the removal of the plates from the prime conductor, and the ſeparation of them, in order to examine their electricity, I found on each plate a poſitive and a negative ſurface; and having replaced them and made the diſcharge, I obſerved that the electricity of all the ſurfaces was changed. I have mentioned this circumſtance, to ſhew how ſmall a difference in the manner of making an experiment, will make an eſſential difference alſo in the reſult. There is ſomething, however, very ſingular in this kind of glaſs, which I believe is owing to its not being properly annealed; for I once met with a plate of it which I found very difficult to charge at all; and when a ſmall quantity of electricity had been forced into it, it diſſipated proportionably ſooner, without the uſe of the diſcharging rod.

In glaſs, properly annealed, whether in the form of plates or jars, prepared for the Leyden experiment, the diſſipation of the electricity is, in ſome ſtates of the atmoſphere, a remarkable, and ſometimes (when there is not a fire in the room) a diſagreeable circumſtance: this effect, however, in the jar itſelf, may be in a great meaſure prevented, by having the uncoated part of the glaſs neatly covered with the beſt varniſh[g]; and I ſhould not omit to obſerve, that Mr. HEMMING's bottle, which retained its charge ſo long, was prepared in this manner.

POSTSCRIPT,

Containing ſome experiments and obſervations on Mr. VOLTA's *machine, by* Mr. TIBERIUS CAVALLO, *with remarks by Mr.* HENLY.

Mr. VOLTA's machine, which occaſioned ſeveral of the preceding enquiries, hath lately been made by Mr. CAVALLO, by coating the glaſs plate (about ſix inches in diameter) with ſealing-wax. With one excitation of this plate he ſoon charged a bottle compleatly, and with that charge pierced three holes in a card, which he hath ſince ſhewed me. If, when this machine acted vigorouſly, he inverted the excited plate, and ſet the braſs plate upon the glaſs, he produced a contrary electricity, but in a much ſmaller degree. If when the ſealing-wax was ſtrongly excited, ſo that ſparks, two inches long, might be drawn from the braſs plate, the excited wax, &c. was placed on an electric ſtand, and the proceſs continued as uſual; the ſparks from the braſs plate preſently dimi-

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(g) The varniſhing ſhould be ſeveral times repeated.

niſhed, and in a ſhort time almoſt totally ceaſed: this, I think, clearly indicates that the electricity in the lower ſurface of the glaſs and the table were mutually affected in the operation, as well as that, in the excited ſealing-wax and the braſs plate(b). I have ſeen one of theſe machines, made by Mr. CAVALLO, act ſo ſtrongly that, upon ſeparating the braſs plate from the ſealing-wax, a flaſh has ſtruck from the braſs toward the table, and it has beſides given a ſtrong ſpark upon the knuckle, when held at upwards of an inch diſtance. If the braſs plate, after being raiſed from the wax, be preſented with its edge toward the wax (lightly touching it) and thus drawn over its ſurface, the electricity of the plate, he obſerves, will be abſorbed by the ſealing-wax, clearly ſhewing the ſtrong negative ſtate in which the excited wax is left on the removal of the braſs plate.

The attraction between the plates is alſo ſometimes ſo ſtrong, that the coated glaſs has frequently been lifted up by the braſs plate from the table; yet in a few days, being carefully placed in a proper repoſitory (in contact with each other) not the leaſt ſign of electricity has been diſcoverable on their ſeparation: ſo far is even this machine from exhibiting perpetual electricity. Indeed, in this particular, it is far exceeded by Mr. GREY's apparatus of the cone of ſulphur in the glaſs, which, on being ſeparated, I have never perceived to fail of exhibiting ſtrong ſigns of electricity, in every ſtate of the weather. To this apparatus I have lately added the improvements of M. ÆPINAS, and find that they fully anſwer his report.

(b) It has been ſuppoſed by ſome gentlemen, that the very ſame quantity of electricity imparted by the finger to the plate on touching it, was emitted again by the plate on removing it from the electric and preſenting it towards the knuckle; and that therefore, in air perfectly dry, this machine would at all times exhibit its phenomena without a freſh excitation of the electric, and thus merit the appellation of a machine for exhibiting perpetual electricity: but the fact above mentioned entirely refutes that ſuppoſition.

THE following paper contains a ſet of experiments which may perhaps lead to ſome curious, uſeful, and important truths in electricity. They are made with the moſt ſimple apparatus, and in the moſt ſimple manner; nothing more being requiſite for this purpoſe than a few ſticks of ſealing-wax (one of them being reſerved as a teſt) to the ends of which the ſubſtances to be examined are to be fixed or tied as occaſion may require, and Mr. CANTON's electrometer, neatly made and properly inſulated. With this ſmall apparatus may almoſt every article that can be propoſed be examined with the utmoſt facility. The animal, the vegetable, the foſſil kingdom, with all the works and combinations of art and manufacture, may afford materials; almoſt any of which, by a ſlight friction againſt woollen cloth or ſilk, will become electrified (either poſitively or negatively, according to the nature of the ſubſtance and form of its ſurface, and the quality and ſurface of the rubber) ſufficiently to ſeparate the balls of the electrometer, ſo as to determine their electricity in a very ſatisfactory manner. This, I think, fully confirms an opinion I have long entertained and mentioned in a former paper, *viz.* that the ſlighteſt friction of bodies of every kind, in every ſituation, may diſturb the electric matter contained in them, though the effect be imperceptible to us, having no electrometer nice enough to diſcover it. Here, therefore, is a boundleſs field for future enquiry; and, to aſſiſt thoſe who may be inclined to proſecute it, I ſhall mention a few general obſervations and precautions, which I have found exceedingly uſeful in the courſe of my own experiments. 1ſt, The air ſhould be dry, and the apparatus clean and warm. 2dly, The ſubſtances to be tried ſhould be perfectly clean. 3dly, When the rubber hath been uſed once or twice, it ſhould be held near the fire or the flame of a candle, not only to prevent its acquiring moiſture, but to take off the electricity left in it by one ſubſtance, before another be examined; for it ſhould always be remembered, that whenever a ſubſtance is made electrical by friction, the rubber acquires the contrary electricity, and this electricity, if it be not carefully taken off as is above directed, will ſometimes remain in it ſo as to confuſe and actually miſlead in the experiments. 4thly, Some minute ſubſtances, as a ſmall leaf, ſeed, or hair, will not be eaſily excited in damp weather; theſe, therefore, as well as the apparatus, ſhould be warmed; for heat, I find, doth always diſpoſe bodies to become electrical. 5thly, The inſulating ſtands, and the ſticks of ſealing-wax, with which the ſubſtances to be examined are connected, ſhould not be rubbed, leſt they, by the friction, ſhould be made electrical, and, acting through the ſubſtance in contact with them, deceive in the experiment. 6thly, The animal ſubſtances, as hair, horn, bone, cartilage, nails, teeth, muſcles, &c. become electrified poſitively, by friction, againſt woollen cloth or black ſilk; and the vegetable creation, with very few exceptions, negatively. The metals differ with reſpect to kinds, form, and ſurface, and may be differently affected by different rubbers. Laſtly, I muſt not omit to obſerve that, among vegetables, I find the hot, acrid, pungent, and aromatic ſubſtances, as the ſpices, &c. to be much more eaſily excited, and ſtronger in their power, than the cold ones, as the ſeeds of gourd, melon, or cucumber. Among the herbs, hemlock and parſley are ſtrong: a ſingle leaf of laurel, bay, yew, roſemary, &c. will be found very powerful; but, as I have before obſerved, this field is indeed immenſe, and life itſelf too ſhort for a compleat inveſtigation. The experiments prove, however, how univerſally the electric matter is diſſeminated; or, in other words, its exiſtence in all bodies; with what readineſs it is excited; and, I think, the conſtancy of its action (though imperceptible to us) as well as its uſe and importance as a principal agent in the greateſt, and to mankind the moſt intereſting, operations in nature. I have encloſed a catalogue, exhibiting at one view the articles I have had an opportunity to try, with their kinds of electricity marked againſt them; hoping this ſpecimen may induce gentlemen of more leiſure to purſue the enquiry.

Hair, wool, down, and many other articles, may be made up in the form of little taſſels, and in this manner readily fixed upon or tied to the end of an electric for experiment.

The following ſubſtances being fixed or tied upon the end of a ſtick of ſealing-wax, and excited by friction againſt a woollen garment or a piece of ſoft black ſilk, became electrified as marked in the columns of the annexed table. The ſtrongeſt in power are diſtinguiſhed by the letter s, and the weakeſt by the letter w.

METALS.

	Wool.	Silk.
A new guinea; a ſmooth ſix pence; a braſs ferule; tin, and tin-foil; enamelled coppcr, s; gilding on leather, s; lead ore; copper ore; iron ore; ſtream tin;	Neg.	Neg.
Milled lead; copper, s; a poliſhed ſteel button, s; a new ſilver ditto; a metal button gilt, s; tutenague ditto, s; iron;	Poſ.	Poſ.
Lead from a tea-cheſt, in which there is a mixture of tin, w;	Neg.	Poſ.
A gilt button, baſket pattern; the juncture at the end of a braſs ferule;	Poſ.	Neg.

ANIMAL

ANIMAL SUBSTANCES.

	Wool.	Silk.
Tortoiſe-ſhell, w; ivory, s; bone, s; horn; lamb's-tooth; horſe's-hoof; deer's-hoof; muſcle of the leg of a deer, s; cartilage, s; ſpur of a young cock; bill, claw, and ſcale from the leg of a turkey, s; ſcale of a carp; the *chryſalis* of a moth, recent from the earth, cleanſed; *craſſamentum* of the human blood exſiccated, w; quills; claw of an unboiled lobſter; cowrie and ſeveral other ſmooth ſhells, s; ſhell of a hen's egg; tail of a ſmall fiſh; thigh of the elephant beetle; a ſmall beetle, ſmooth ſurface; human hair; red and white horſe's and bullock's hair, s; hog's briſtles, s; wool; ſilk from the worm, w; oyſter-ſhell, ſmooth ſurface;	Poſ.	Poſ.
Mother of pearl, and ſeveral other ſhells;	Neg.	Poſ.
Muſcle and cockle-ſhells, recent; a recent ſnail-ſhell, rough ſurface; *elitra* of the ſtag-beetle; oyſter-ſhell, rough ſurface;	Neg.	Neg.

VEGETABLES.

	Wool.	Silk.
Rind of cheſtnut, s; Barcelona nut-ſhell, s; caſhew nut, s; cocoa nut-ſhell poliſhed; brazil; *lignum vitæ*; black ebony, s; box, w; cane, s; *quinquina*, or Peruvian bark, s; tamarind-ſtone; coffee-berry roaſted, s; nutmeg, s; ginger, s; white pepper, freed from the huſk, s; cinnamon, s; cloves, s; mace, s; all-ſpice, s; capſicum, both ſides of the pod, s; hemlock, s; a clove of garlic; ditto of eſchalot, freed from the huſk, s; a green onion, s; rue, s; cork, s; leaves of laurel, bay, yew, holly, roſemary, with their berries, s; parſley, s; leaf of turnip; ditto of Savoy cabbage, s; celery, s; ſago, s; thime, s; carrot; turnip; potatoe; an acorn, s; rind of Seville orange, s; a large Windſor bean, s; a white pea; root of the white lily; ſnow-drop root; ſeeds of gourd, melon, cucumber, w; a ſpecies of long-moſs, w; an apple, s; down of the cotton-ruſh, w; ſea-flag; leaf of the American aloe, s; cotton, w;	Neg.	Neg.

	Wool.	Silk.
Hemp; flax; ſtalk of the tobacco-leaf; ſpike, from the leaf of the American aloe; *palma-chriſti* nut; horſe-radiſh;	Neg.	Poſ.
A white kidney-bean, ſmooth ſurface; black negro of the ſame; ſcarlet of the ſame;	Poſ.	Poſ.
CORALLINES.		
Sea-fan, the horny part, w; rough coral, w;	Neg.	Poſ.
Spunge, w; coral poliſhed, w;	Poſ.	Poſ.
SALTS.		
Allum, w,	Neg.	Neg.
Borax, Nitre purified, ſmooth ſurfaces;	Poſ.	Poſ.
FOSSIL AND MINERAL SUBSTANCES.		
Common pebble-ſtones of all colours, s; marble, s; pit-coal, s; black-lead, w; jet, s; *aſbeſtos*; mineralized ſulphur; thunder-bolt ſtone; *cornu-ammonis*; ſhark's-tooth; coat of petrifaction;	Neg.	Neg.
Several ſmooth native cryſtals; brown Iceland ditto; *talc*, s; Ceylon pebble, ſmooth and tranſparent; agate, s; cornelian; amethyſt, s;	Poſ.	Poſ.

A ſpecimen

	Wool.	Silk.
A ſpecimen of *gypſum*,	Neg.	Poſ.
ARTIFICIAL SUBSTANCES.		
Staffordſhire ware glazed; China ware, s; Wedgwood's ware glazed, s; whale's fin prepared, w; writing-paper; parchment, s; ſheep's gut,	Poſ.	Poſ.
Tobacco-pipe, s; Wedgwood's ware unglazed; elaſtic gum, s; hard undercruſt of a leaf; a tallow-candle, w; oiled ſilk; painted paper, s; ſilver, burnt into glaſs, unburniſhed; pearl-barley, w; Indian ink, w; blue vitriol, s,	Neg.	Neg.
Dr. LEWIS's glaſs porcelain,	Neg.	Poſ.

Silver burnt into glaſs, burniſhed, could not be excited either with the woollen or ſilk. It is ſuppoſed that the ſubſtances being ſo intimately incorporated or blended together, the friction at the ſame time excited both the ſubſtances, ſo as to counteract and deſtroy the effect of each other.

In theſe experiments I have been aſſiſted by Mr. CAVALLO and Mr. ADAMS, who have carefully repeated them in my preſence. It may be proper to obſerve alſo, that the white pea, a ſcarlet bean, and the thorn from the American aloe[(b)], being rubbed upon new, fine, claret-coloured cloth, became weakly electrified poſitively.

A lock of black hair from a young colt I have obſerved to become very weakly electrified negatively, when excited either with wool or ſilk.

It will be proper to obſerve, that the rubber of woollen cloth, which I uſed in the preceding experiments, was a part of the coat or waiſtcoat which I happened to wear at the time; but being deſirous to try the effect of another, I took a piece of fine, new, white flannel, and uſing that ſide of it which is free from knap, I perceived a remarkable difference; *viz.* the copper and other buttons, the different ſtones, ſhells, China ware, moſt of the animal ſubſtances (hair excepted) and all the vegetable ones, which with the former rubbers were poſitively, being now negatively electrical; but thoſe which were negative with them, I found to be negative with theſe alſo[(i)]. In all the experiments with the flannel, I had hitherto

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(*b*) All theſe ſubſtances have ſmooth ſurfaces.

(*i*) On this account an ingenious friend of mine propoſed the following queſtion, *viz.* Whether, if the electric matter were inherent (as I aſſerted) in the different ſubſtances I examined, the kind of electricity could be changed by the uſe of different rubbers? I reminded him of Mr. CANTON's experiments with a glaſs tube, and informed him, that a ſtick of ſealing-wax becomes poſitively electrified by dipping it in quickſilver, or exciting it with a ſlip of tinfoil; that a ſmooth glaſs tube may be made negative by drawing it croſs-wiſe over hitherto warmed the ſubſtances, but kept the rubber cold; ſuſpecting that, in ſome caſes, the reſult might be different from what it is when the rubber is warm and the ſubſtance cold: but this, with the effect of cloths of different textures and colours, ſilks, ſattins, velvets, leather dreſſed in oil, and in allum, &c. uſed as rubbers, I have not had leiſure to determine. A ſmall turnip and a potatoe, which I could not excite at all with either of the rubbers when they and the ſubſtances were cold, I excited in a very ſmall degree with the flannel a little warmed; but very ſtrongly when the flannel and the reſpective articles were, each of them, moderately warm. A ſprig of celery acted very powerfully when the flannel only had been previouſly warmed[k]. As in all caſes the rubber is affected with an electricity contrary to that of the ſubſtance rubbed, it will be ſufficient for

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over the back of a cat, or by exciting it with a dry, warm rabbit's ſkin; that a ſmall coated bottle may be charged with a ſlip of writing-paper, excited by drawing it briſkly between the fingers of a dry hand ſo as to pierce a hole in a card; that the dry leathern cover of a book may be made ſtrongly electrical by the friction of a dry hand, and that its electricity is remarkably ſhewn by touching it with an inſulated button, in the form of the plate to Mr. VOLTA's machine. He then acknowledged, that ſuch an objection as he had ſtarted muſt certainly be groundleſs.

(*k*) A *palma-chriſti* nut was excited very ſtrongly with the flannel, weakly with my coat, and not all (in a room where there was no fire) with the black ſilk. I have alſo to add, that ſome particular ſubſtances, though negatively electrical when heated, become poſitive when cold, by friction againſt the very ſame rubber.

many

many purpoſes to uſe a rubber with a handle of glaſs, wax, &c. with which the electricity of many fixed bodies, gems that are ſet in metals, &c. and other articles that it would be improper to divide or remove, may be determined. Such rubbers of different forms have been conſtructed and ſatisfactorily employed in a variety of inſtances by Mr. ERRINGTON and Mr. CAVALLO, who have extended their enquiries far beyond the limits at which I deſiſted; their collection of animal, vegetable, foſſil, and artificial ſubſtances, added to my catalogue, amounting to almoſt one thouſand articles.

CONCLUSION.

AT the concluſion of the ſecond part of the preceding paper, in my remarks upon the electricity of chocolate, I have obſerved, that many and great diſcoveries have been made in this age, reſpecting the action, influence, and effects of electricity; but it is a queſtion that hath been frequently put to electricians, What is electricity? For my own part, I have generally choſen (perhaps for want of a better anſwer) to reply by a ſimilar queſtion, *viz.* What is air? or, what is water? For, as theſe are underſtood to be fluids diſtinct from all others, and diſtinguiſhed by the names they bear, ſo have I ever conſidered electricity as a fluid *ſui generis*, and properly characteriſed by the term electricity, electric fluid, or electric matter; and have always avoided the term electric fire, as conveying a confuſed idea of actual inflammation, burning, &c.: but I now begin really to doubt, whether another appellation might not be applied with greater propriety; whether electricity may not be conſidered as a pure, ethereal, elementary fire, inherent in all bodies, intimately connected or blended with an earthy or other baſe, and apparently, though not actually, remaining in it in a quieſcent ſtate, till rouſed into action by ſome proper application, as motion, or rather friction, which may, and probably does, collect it in our experiments. (But can motion convey inſtantaneouſly that which is not material, but only a quality, a property, an accident, or affection, of matter, through ſuch circuits as thoſe of Dr. WATSON, and produce ſuch aſtoniſhing effects at the interruption of thoſe circuits? Beſides, in Dr. FRANKLIN's moſt curious and deciſive experiment of charging the Leyden bottle with its own electricity, the glaſs undergoes no friction whatſoever; but the electricity inherent in it is ſimply exhauſted from one of its ſurfaces, and forced round upon the other by the electrical apparatus: the ſame may be aſſerted of bodies preſented toward a conductor negatively electrified, or to the inſulated rubber of the electrical machine.) That it may be ſaid to reſide in vegetables, and is extracted together with their oil; that in fermentation, effervefcence, and putrefaction, it flies off in the phlogiſtic vapour thence ariſing (ſee note 1. at the concluſion of this paper); that in diſtillation it is diſengaged and brought over in an ardent ſpirit, in which it reſides, retaining its original properties in a purer baſe; that, ſince by the colliſion of flint, ſteel, &c. actual fire is inſtantaneouſly produced (as in the inſtance of the dry axle of a carriage, which, by the friction of the nave againſt it, ſoon takes fire) ſo by the friction of other bodies, which by long perſeverance would produce the ſame effect, this latent fire may be firſt excited, and its appearances, though unobſerved, be thoſe we term electrical. A wind-mill, when it works under the break (as the millers term it when no iron is concerned) ſoon catches fire (the mill-ſtones, when no corn is between them, produce the ſame effect, though the motion be the ſame in both caſes) and many a mill hath been conſumed by this means. The method uſed by the Indians, of producing fire by the friction of two pieces of wood againſt each other is well known; and in all theſe caſes may not the firſt effects of the latent fire, thus rouſed into action, be the production of thoſe very appearances we call electrical? See notes 2. 3. 4. 5. and 6.

This thought, I confeſs, remained ſo ſtrongly impreſſed upon my mind, that I requeſted ſome of my friends, who had a better opportunity than myſelf, to make the trial. For this purpoſe ſome pieces of wood were baked in an oven, in order to expel the moiſture, and prepare them for the experiment. When they were cooled, a friction was begun, which, as I expected, ſoon produced electricity; one piece of the wood being excited poſitively, the other negatively, as I have ſince myſelf ſeveral times experienced. Had the friction been continued, the production of actual fire might perhaps have been the conſequence. May not, therefore, the production of actual fire be the *ultimum* of electricity? or, in other words, electricity the firſt effect of latent fire thus rouſed into action; actual fire, the ſecond; and inflammation and diſſolution, its third and greateſt effort? like fermentation, producing firſt, wine; ſecondly, vinegar; laſtly, putrefaction. To give ſome countenance to this ſuppoſition, let ſome of the effects of electricity and fire be placed in a comparative view. Firſt, a ſmall iron wire, held in the flame of a candle till it acquires a white heat, will frequently burſt into little balls, flying off in all directions. The ſame effect is produced by a flint and ſteel; and in a ſuperior manner, by a ſtrong charge of electricity, or a flaſh of lightning paſſing through ſuch a ſmall wire; the balls then appearing, on examination, to be little more than the *ſcoriæ* of the metal. The effect of electricity, lightning, and fire, in deſtroying the power of the artificial or natural magnets, is a circumſtance that hath been often remarked, and repeatedly publiſhed. The effects of electricity, in common with fire, on proof-ſpirit, gun-powder, *phoſphorus*, dry lint, and many other ſubſtances, muſt occur to every gentleman converſant in theſe experiments; indeed the parallel might be continued much further. But it may be aſked, if this be really the fact, ſhould not metals become electrical by friction? I anſwer, they are readily excited, provided they be firſt properly inſulated; (but if metal be rubbed againſt metal, the phlogiſton or latent fire, if I may be allowed the expreſſion, is ſo nearly proportioned in the two metals, that the equilibrium is reſtored as ſoon as deſtroyed, from the very nature of the baſe, which is the moſt perfect conductor we are acquainted with) to illuſtrate this, let it be remembered, that though the hydroſtatic paradox may be readily explained, yet the fluid muſt be confined in a proper veſſel; and though the weight, the ſpring, and the compreſſibility of the air, be eaſily demonſtrable, a ſuitable apparatus muſt neceſſarily be employed for each purpoſe.

It is a queſtion by no means decided, how the clouds become electrified? But if we ſuppoſe the electric matter to be a pure, ethereal, elementary fire, reſident in all bodies; that the great proceſs of vegetation is carried on by means of this ſubtile, active, volatile, and pervading element; that it is continually exhaling from all the vegetable tribe; that as evaporation is a remarkable agent in the cooling of heated ſubſtances, that is, a good conductor of their fire, as I am well aſſured it is of electricity; may we not conclude, that this is one great cauſe of the clouds becoming at times ſurcharged with this fluid? The great effect of electricity in promoting vegetation, hath been fully proved by Dr. DE MAIMBRAY, the abbé NOLLET, Mr. JALLABERT, and other gentlemen, and was very remarkable in that year when the fatal earthquake happened at Liſbon. Dr. STUKELEY's obſervations on the frequent appearances of fire-balls, coruſcations, and *auroræ boreales*, at this time (which I well remember) deſerve to be particularly noticed; and it is generally remarked, that thunder-ſtorms are preceded by a continuance of hot weather, and that a moderate temperature immediately ſucceeds the ſtorm. The remarks and obſervations of the worthy Dr. HALES on this ſubject ſeem alſo to merit peculiar attention. Further, as the rays of the ſun, concentrated by a powerful burning mirror, will produce a fuſion of metals, and inſtantly reduce a number of ſubſtances preſented to the focus to a *calx*, as the ſame effect is in many caſes produced by a ſtroke of lightning; and as the colours of the electric and ſolar light are equally diviſible by the priſm; may not theſe alſo bear ſome kind of relation to each other[l]? Upon the whole, is there not an high degree of probability in the ſuppoſition, that light, fire, phlogiſton, and electricity, are only different modifications of one and the ſame principle? See notes 7. 8. and 9. A ſimilarity in ſeveral of the phenomena of electricity and magnetiſm hath been long ſince pointed out by Dr. PRICE, from M. ÆPINAS; and the effect of heat on both admirably diſplayed by Mr. CANTON. Of all the ſubſtances I have yet examined, the moſt difficult to excite, I obſerved to be a fine, ſmooth, unarmed load-ſtone, and a piece of black lead; theſe ſeemed to bid defiance to all my rubbers: at length, however, with a piece of new flannel they were both excited, in a very ſmall degree, negatively. In ſhort, I have not yet met with a ſingle article (on which the experiment could be tried) that I could not, with one or other of my rubbers, make in

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(*l*) Many other particulars might be adduced in this place; but they are purpoſely omitted, this paper being already extended far beyond the limits originally intended by the author.

ſome degree electrical. The laws by which all theſe fluids are governed, and what conſtitutes the preciſe difference between them, may yet, perhaps, by ſome fortunate philoſopher, by a train of juſt reflexion, and a ſet of happily contrived and well-conducted experiments, be much farther elucidated. Laſtly, I do not ſpeak of theſe things as facts of which I am abſolutely convinced; but earneſtly wiſh to recommend them to the ſerious conſideration of future enquirers. From what hath been ſaid, however, I apprehend it will ſcarcely be doubted, that electricity, whatever it be (as I have often remarked) is one of the greateſt and moſt important agents in the operations of Nature; that the effects of lightning, therefore, are but as diſcords in her harmony; and, though ſingly conſidered, they may appear unpleaſing notes, yet perhaps may be neceſſary to fill up and compleat her grand and general chorus.

NOTES ON THE CONCLUSION.

1. I am juſt informed by Mr. ADAMS, that Mr. CLARKE, an ingenious gentleman from Ireland, hath lately proved, to the ſatisfaction of ſome of the ableſt chemiſts there, that the variety of airs produced by different gentlemen

in their pneumatical reſearches (that produced from the *calces* of metals perhaps excepted) are only phlogiſtic vapours ariſing from, and partaking of, the qualities of the ſubſtances from which they are diſengaged.

" The vapour of fermentation is much more ſubtle " than common air, it paſſes through bodies which " would be impenetrable obſtacles to the latter.

" Mr. DE SMETH was not able to retain it by the aid " of lutes: a moiſtened bladder, tied over the mouth of a " veſſel which contained ſome fermenting matter, was " not at all inflated during the height of fermentation.

" Dr. PRIESTLEY has obſerved, that the fixed air from " fermenting beer combines eaſily with the vapour of " water, as alſo with the ſmoke of roſin, ſulphur, and " other electrical ſubſtances.

" If it were permitted me to indulge in conjectures, I " ſhould ſay that ſome experiments induce me to be- " lieve, that every elaſtic fluid reſults from the combina- " tion of ſome ſolid or fluid body with the inflammable " principle, or perhaps even with the matter of pure " fire; and that on this combination the ſtate of elaſti- " city depends." See HENRY's tranſlation of M. LAVOISIER's Eſſays, phyſical and chemical.

Mr. LANE, in his curious and moſt important experiment of diſſolving iron in water impregnated with fixed air, obſerved, that after the water ſo impregnated had been paſſed through a cloſe filtering paper, it was rendered quite tranſparent, the iron being in perfect ſolution. This clear liquor he endeavoured to preſerve in its tranſparent ſtate, by uſing every means that then occurred to him to retain the elaſtic vapour, but without ſucceſs, for in a few hours the tranſparency diminiſhed: afterwards the liquor became opaque, and depoſited the iron that had been diſſolved in it.

2. Several gentlemen have obſerved, that in working their electrical machines with great velocity, as heat was produced by the friction, the electricity was proportionably leſſened.

3. Mr. ERRINGTON, a gentleman who often recreates himſelf with mechanical operations, frequently obſerved, that after he had been for ſome time briſkly working his drill, the ſtring of it became ſtrongly electrical.

4. Mr. CAVALLO, who ſometimes amuſes himſelf with the violin, having played a few ſprightly airs, examined at my requeſt the hairs of the bow, and the ſtrings of the inſtrument, and found by his electrometer that both of them were electrical; the former in a *plus*, the latter in a *minus* ſtate. In this caſe, the roſin contributes to

the electricity. Perhaps a tenor or baſs-viol might produce the effect in a greater degree.

5. Mr. CAVALLO likewiſe informs me, that taking two pieces of broken China ware, he ſtruck the edges of them briſkly together, and produced ſparks of fire, but no electricity. He then rubbed the broader ſurfaces gently together, and produced a ſtrong electricity; poſitive in one piece, negative in the other. This experiment I have ſeveral times repeated to my entire ſatiſfaction.

6. I have myſelf obſerved, that two glaſs tubes, rubbed briſkly together, produce a vivid purple light and ſtrong phoſphoreal ſmell, but no attraction or repulſion; but two pieces of plate glaſs, each two inches long and one inch broad, warmed and rubbed gently againſt each other, produce electricity, negative in one piece, poſitive in the other. Both glaſs and amber I have alſo made electrical by blowing upon them (previouſly warmed) with a pair of bellows.

7. Platina, in the pureſt ſtate to which it could be reduced by chemiſtry, and on which Dr. LEWIS informed me that the ſtrongeſt fires he could raiſe had no further effect, I have been able to fuſe in a ſmall degree, by a ſtrong charge of electricity. Phil. Tranſ. vol. LXIV. p. 416.

8. Since the learned and accurate F. BECCARIA publiſhed the account of his curious experiment of revivifying the *calces* of metals by electricity, it hath been repeated with perfect ſuccefs by ſeveral other gentlemen.

9. With reſpect to earthquakes, upon this hypotheſis Dr. STUKELEY'S and the rev. Mr. MITCHEL'S ingenious theory may both be near to truth, as the difference between them will conſiſt more in words than in facts. See a moſt curious and aſtoniſhing effect of evaporation produced by electricity in Dr. FRANKLIN'S Experiments and Obſervations, firſt edit. p. 415. Perhaps it may not be improper to mention in this place the following experiment, which I made long ſince myſelf. A pretty large wine-glaſs being nearly filled with water, two wires, terminated by ſmall braſs balls, were hung oppoſite to each other upon the brim of the glaſs, ſo as to let the balls deſcend to about half the depth of the water. The communication being then compleated by a chain, a jar containing three ſquare feet of coated ſurface, was diſcharged through it. The conſequence was, the ſtem of the glaſs was broken in two places; the bowl was ſhivered perhaps into a thouſand pieces, and ſcattered with the water in all directions: part of it flew into my face, and ſo much upon the apparatus, that I remember it put an end to my experiments for that time. I had neglected to cover the glaſs, being deſirous to ſee the

effect of the charge paſſing through the water; not ſuſpecting the danger of the electricity evaporating part of it, and exploding with ſuch violence as might have been attended with very diſagreeable conſequences.

10. That water-ſpouts are really occaſioned by electricity I have long ſuſpected, from ſeveral circumſtances; but Mr. GEORGE FORSTER, F. R. S. in his curious remarks and circumſtantial deſcription of one of theſe phenomena (Voyage round the World, vol. I. p. 191.) ſeems to have confirmed this matter beyond a doubt: the form of the column, the hail-ſtones which fell at the time, and the flaſh of lightning which appeared at the disjunction of the tube, are, I apprehend, as complete proofs as can be given, or as the caſe can admit or require.

11. Some gentlemen have ſuppoſed, that the electric matter is the cauſe of the coheſion of the particles of bodies. If the electric matter be as I ſuſpect, and my experiments and the foregoing notes ſeem to prove, a real elementary fire inherent in all bodies, that opinion may probably be well-founded; and perhaps the ſoldering of metals and the cementation of iron by fire may be conſidered as ſtrong proofs of the truth of their hypotheſis.

12. Dr. PRIESTLEY obſerves (Experiments and Obſervations on Air, vol. I. p. 280.) That it is probable, that elec-

tric light comes from the electric matter itſelf; that this being a modification of phlogiſton, it is probable that *all light* is a modification of phlogiſton alſo; and that, prior to his deductions from electrical phenomena, it was pretty evident that light and phlogiſton are the ſame thing in different forms or ſtates. Dr. PRIESTLEY's third volume on the ſame ſubject was not publiſhed till the laſt ſheet of my paper had been compoſed, and a proof ſtruck off. In the appendix to that volume I find ſo curious an article in a letter from ſignor VOLTA to the Doctor, that I ſhall take the liberty to tranſcribe a part of it, as a very important addition; *viz.* " I fire inflammable air " by the ſimple electric ſpark, even when the electricity " is very moderate, which explains the *ignes fatui*, pro- " vided they conſiſt of inflammable air iſſuing from " marſhy ground by the help of the electricity of fogs " and by falling-ſtars, which are very probably thought " to have an electrical origin.

" I do not know whether you have ever tried the effect " of the Bolognian phoſphorus on air. It phlogiſticates it " in the higheſt degree, and the diminution it occaſions " takes place very quickly, and is altogether ſurpriſing; " but for this purpoſe the phoſphorus muſt be good, " and the weather not too cold."

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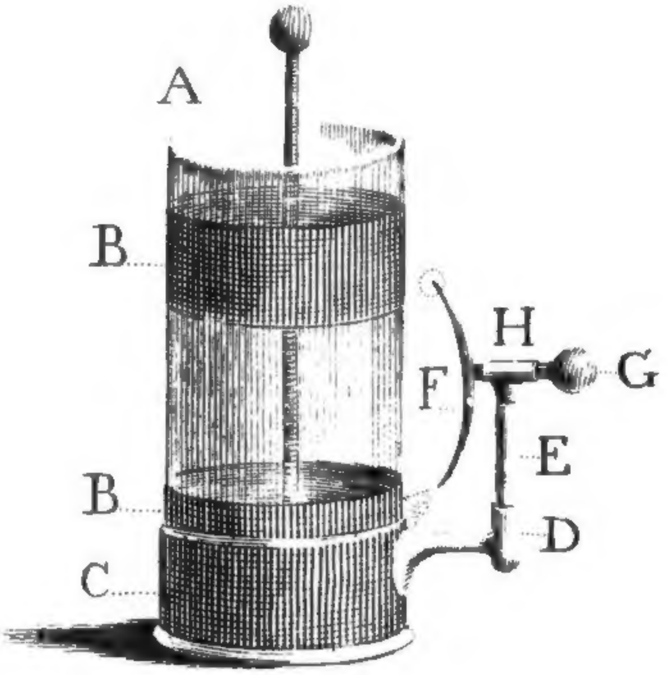

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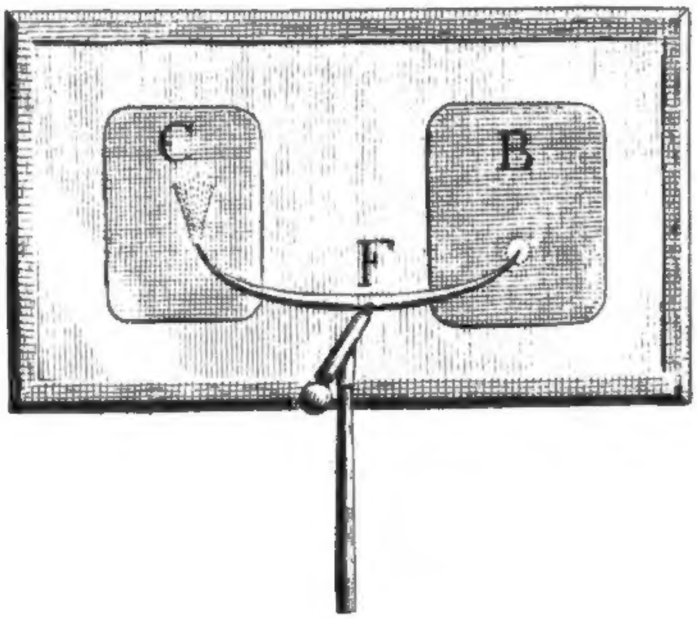

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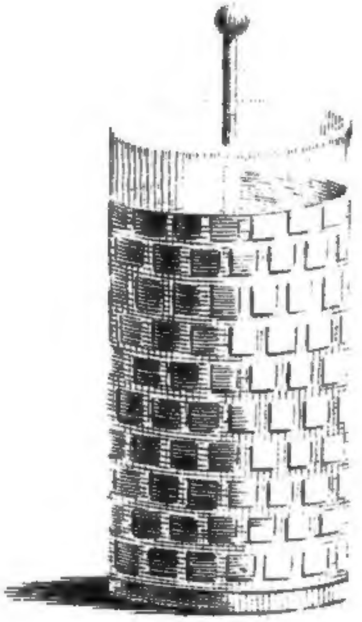

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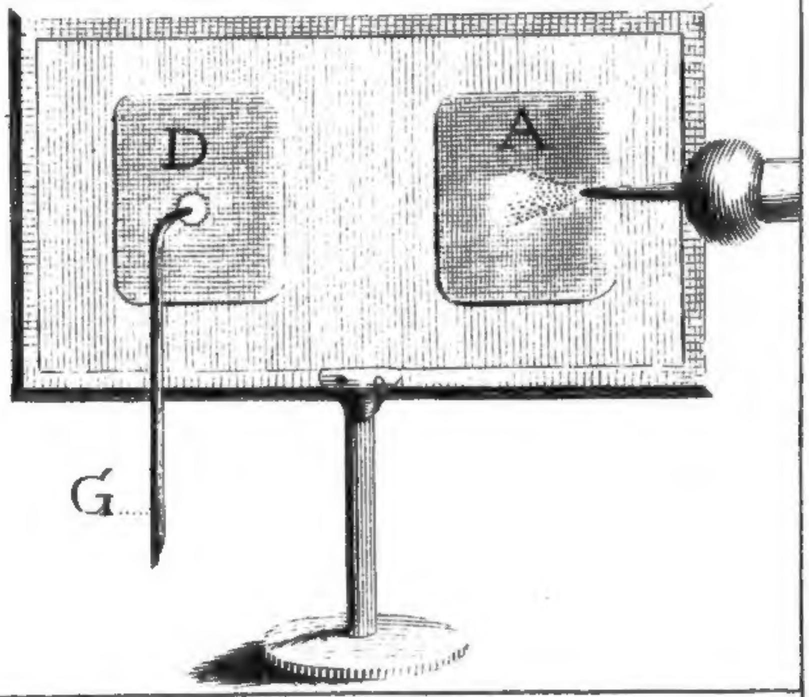

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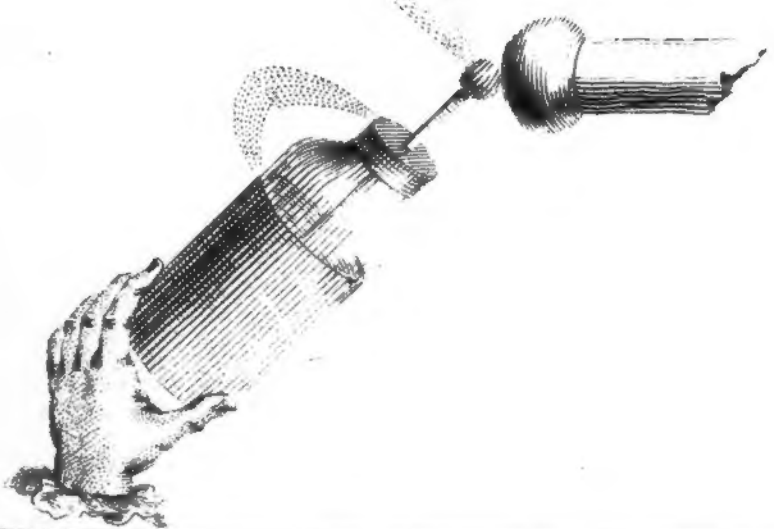

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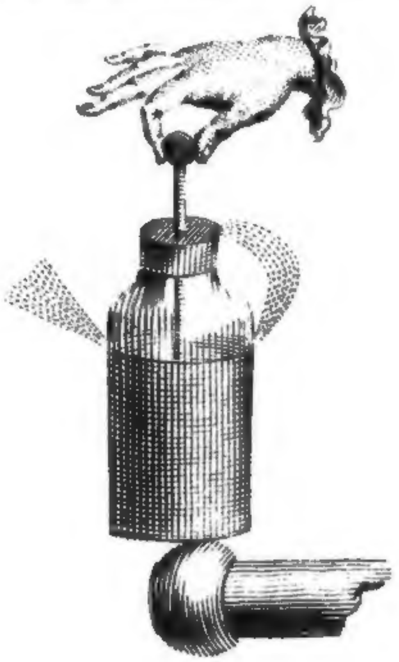

Basire. Sc.

Since the preceding papers were preſented to the Royal Society, I have ſeen and heard of ſuch a number of curious remarks, obſervations, and diſcoveries on light, fire, phlogiſton, and electricity, which tend to illuſtrate and confirm the opinions I have advanced, that I would beg leave to add, that, had I ſeen or known of ſeveral of thoſe excellent pieces in time, I ſhould certainly have availed myſelf of ſuch important labours, and have ſpoken of the ſubjects above-mentioned with a greater degree of confidence. The authors I allude to are, BOERHAAVE on Fire; STAHL on Phlogiſton; Dr. PEMBERTON on Fire; Dr. HIGGINS on Light; the celebrated MACQUER, particularly in his Memoir on Phlogiſton, in the abbé ROZIER's Journal for Nov. 1776; a Memoir by Mr. OPOIX on Phlogiſton and Light; Mr. ACHARD's Electrical Experiments on the Ice of diſtilled Water, frozen in a degree of cold exceeding what we ever experience in this country; with plates of which ice he not only performed the Leyden experiment, but even excited it by friction like glaſs (ſee the Abbé ROZIER's Journal for Nov. 1776); and laſtly, M. KOESTLIN's curious and moſt valuable experiments on the influence of electricity, in the production and ſupport of animal and vegetable life, particularly his diſcovery that vegetation was actually retarded by electrifying his ſeeds negatively.

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